

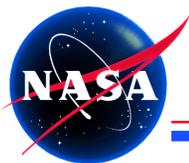
# **Spatial Resolution of IKONOS Panchromatic Images: Characterization Based on Edge Responses**

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# Contributors

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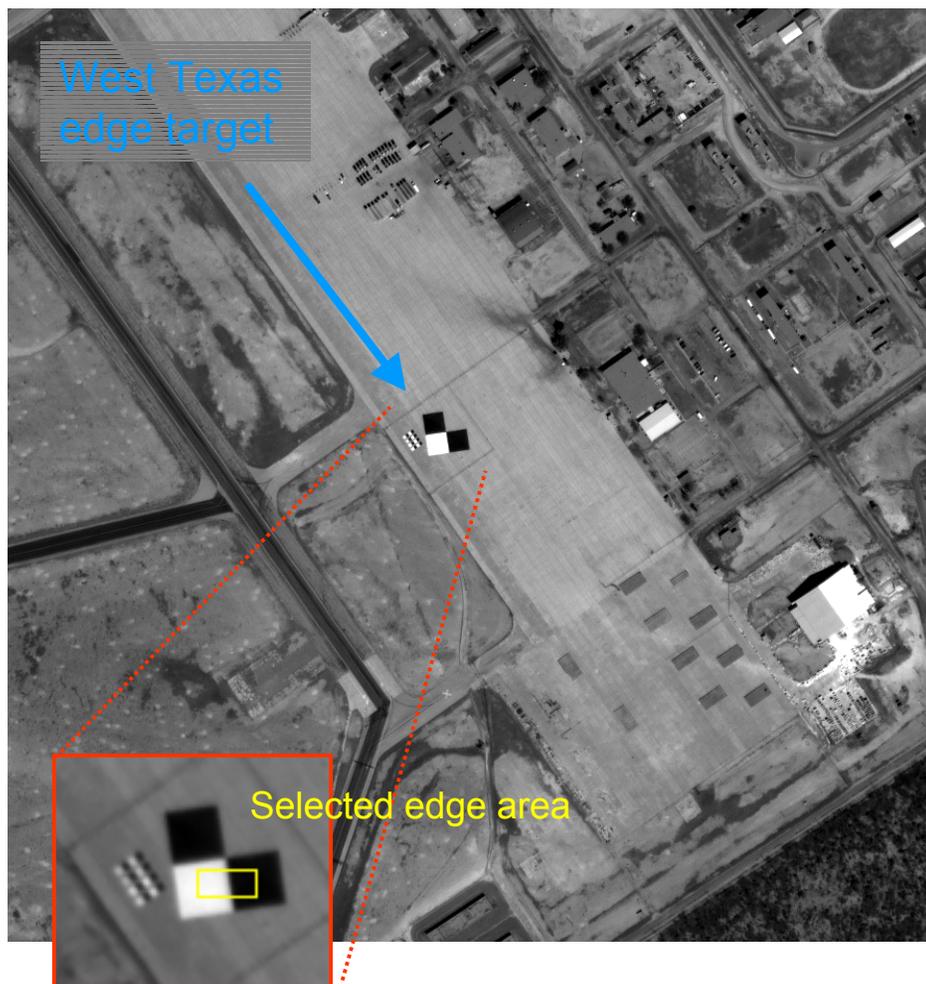




# IKONOS V&V: Spatial Resolution

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- *Goal:* use edge response to characterize spatial resolution of IKONOS panchromatic products: georeferenced images in UTM projection, processed with radiometric correction and MTF compensation, resampled using a bicubic method
- *Approach:* characterize spatial resolution by FWHM of line spread function and MTF at Nyquist frequency
- *Extra:* evaluate effects of MTF compensation and collection elevation angle



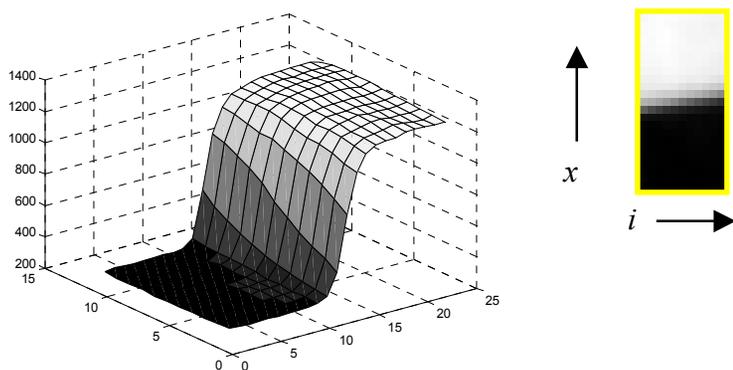


# Modified Knife-Edge Technique

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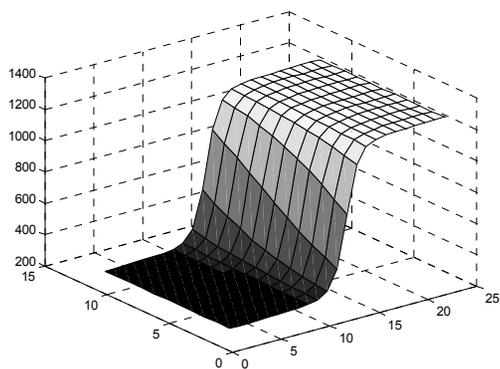
Selected edge area includes a set of edge responses, each one with edge position shifted by a fraction of pixel from an adjacent one

Nonlinear least-square fit of a two-dimensional function which is a superposition of three sigmoidal functions



$$e_i(x) = d + \sum_{k=1}^3 \frac{a_k}{1 + \exp\left[\frac{x - b_1 i - b_2}{c_k}\right]}$$

Actual intensity in the edge area



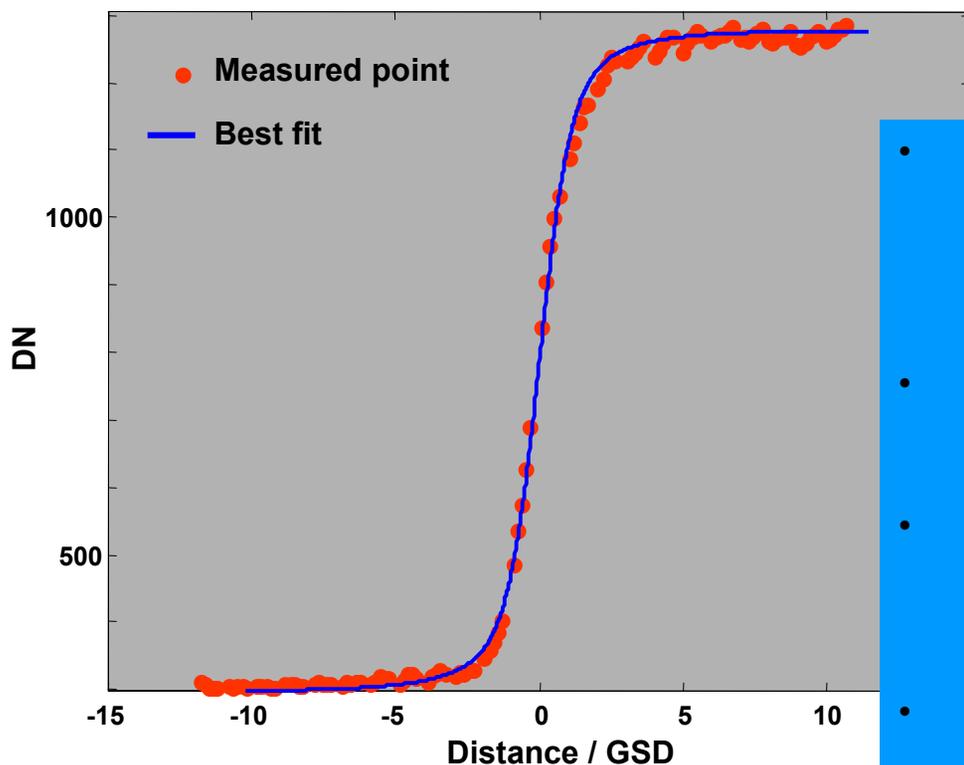
Best fit with the sigmoidal functions

- Optimized parameters:  $a_1, a_2, a_3, b_1, b_2, c_1, c_2, c_3, d$
- Position and orientation of the edge, described by parameters  $b_1$  and  $b_2$ , are found simultaneously with the parameters characterizing spatial resolution ( $c_1, c_2$ , and  $c_3$ )
- Measured edge tilt:  $\theta = \tan^{-1}(b_1)$
- Distance is scaled by cosine of the edge tilt angle:  
 $x' = x \cos(\theta)$

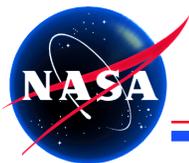


# Measured Edge Response

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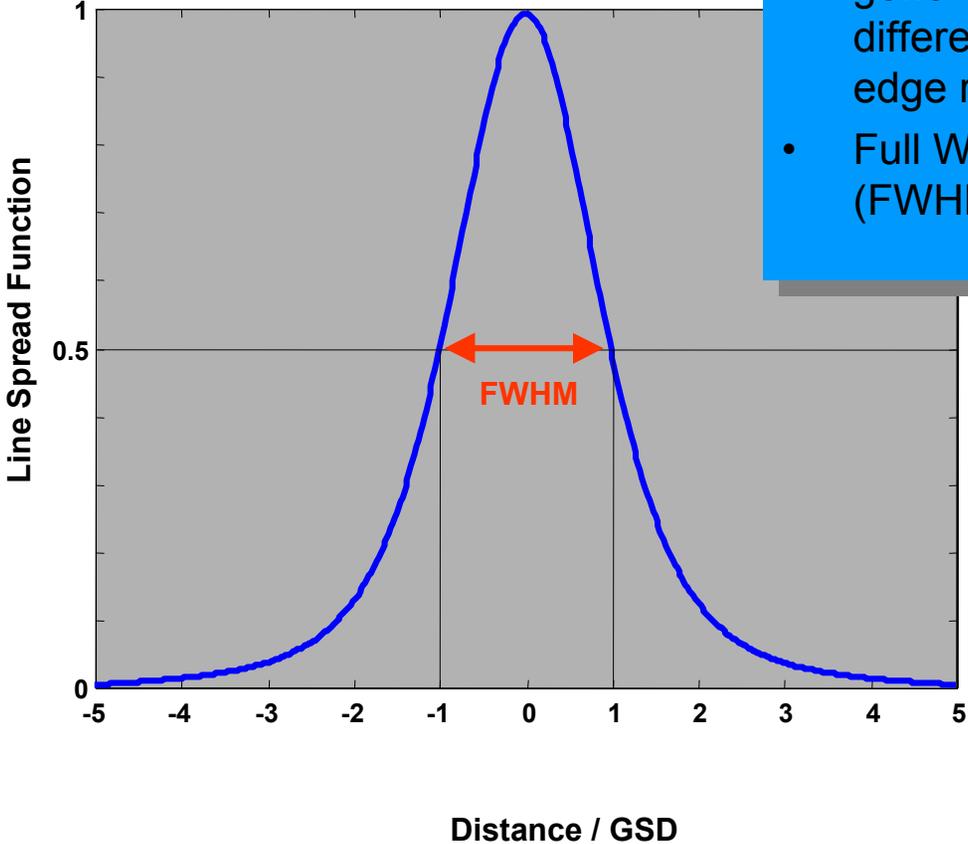


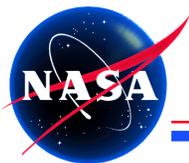
- Finding position and orientation of the edge allows for shifting of the edge responses to a single reference location so that all the edge points are aligned
- Superimposing all the shifted edge responses creates a new one with a finer spatial sampling
- Optimized edge response is generated with arbitrary spatial resolution from the best-fit parameters
- Quality of fit is examined: Is the superposition of sigmoidal functions appropriate to model the edge response?



# Line Spread Function

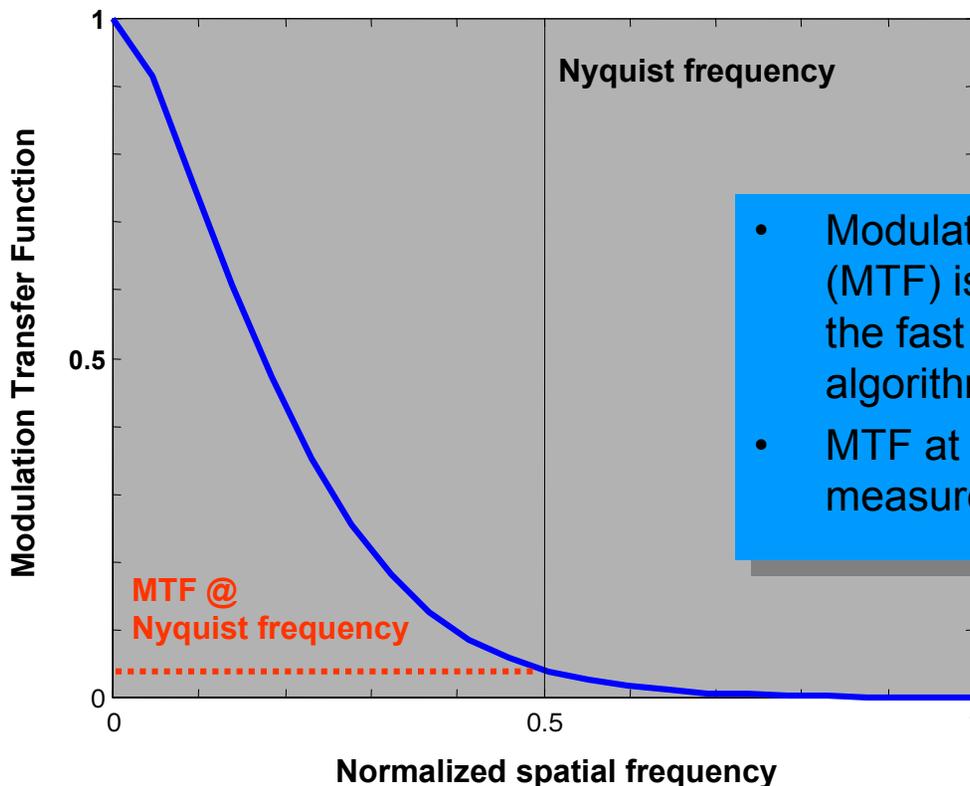
- Line-spread function (LSF) is generated by numerical differentiation of the optimized edge response
- Full Width at Half Maximum (FWHM) of the LSF is calculated





# Modulation Transfer Function

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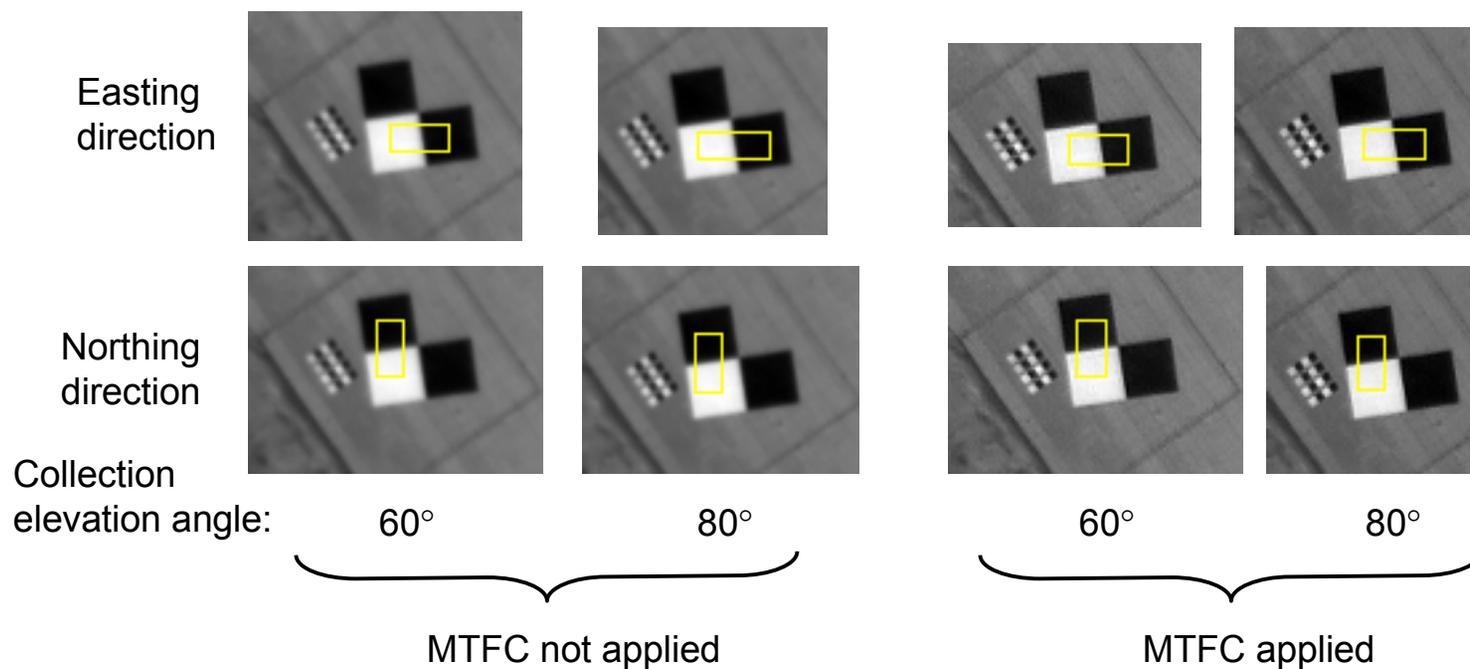
- Modulation Transfer Function (MTF) is generated by applying the fast Fourier transform (FFT) algorithm to the LSF
- MTF at Nyquist frequency is measured

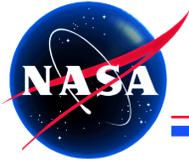


# Selected Edge Areas

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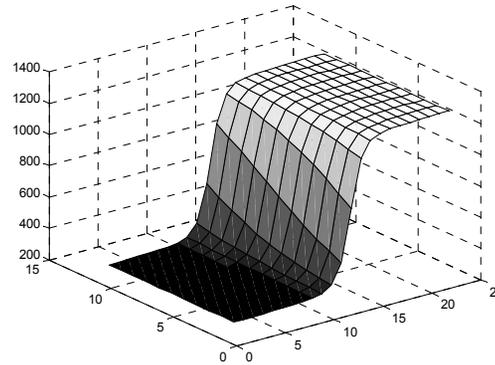
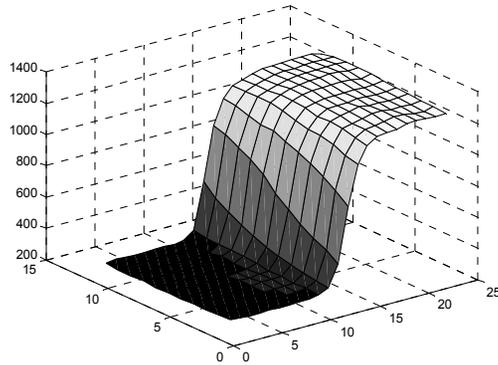
Rectangular edge response regions selected for analysis of spatial resolution from the images acquired on March 26, 2000.



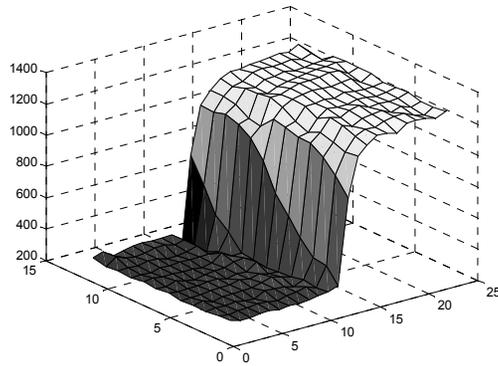


# Edge Responses: Easting, 60°

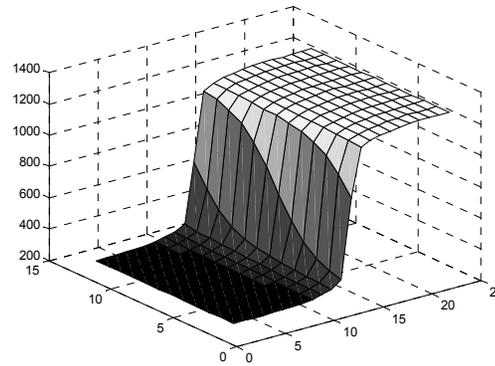
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MTFC  
not applied

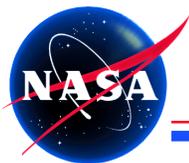


Measured



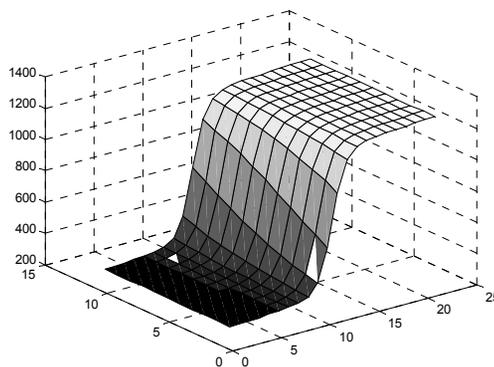
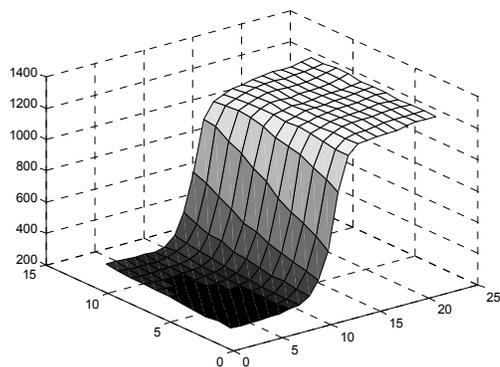
Best fit

MTFC  
applied

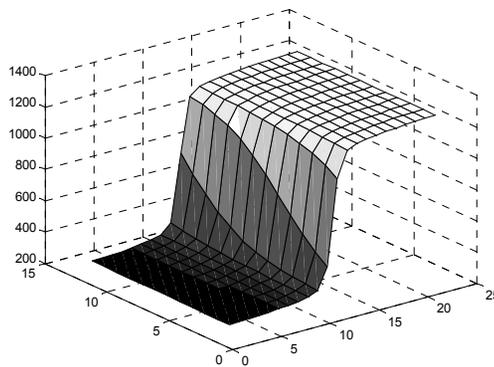
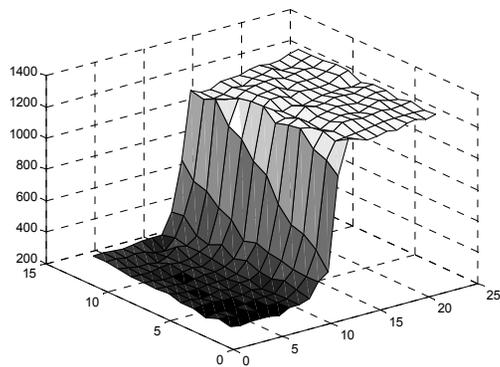


# Edge Responses: Northing, 60°

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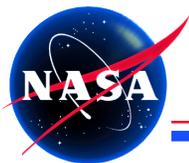
MTFC  
not applied



MTFC  
applied

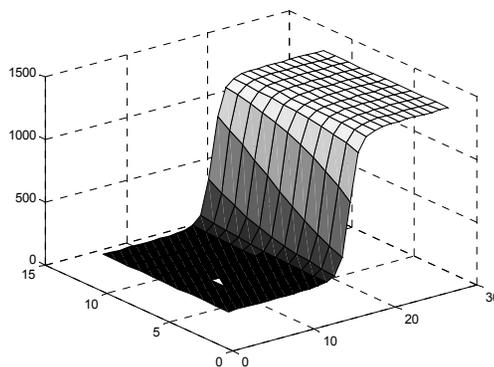
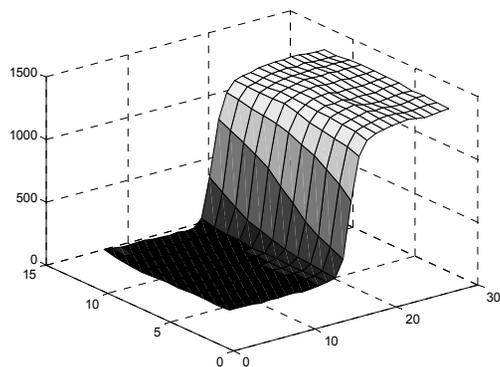
Measured

Best fit

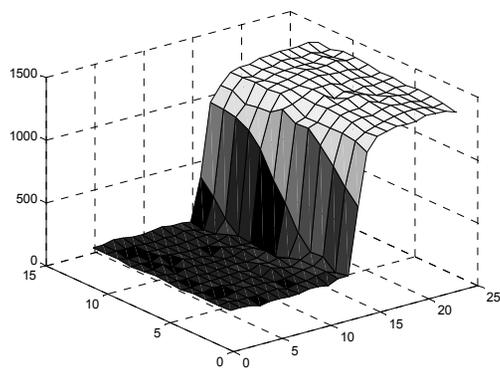


# Edge Responses: Easting, 80°

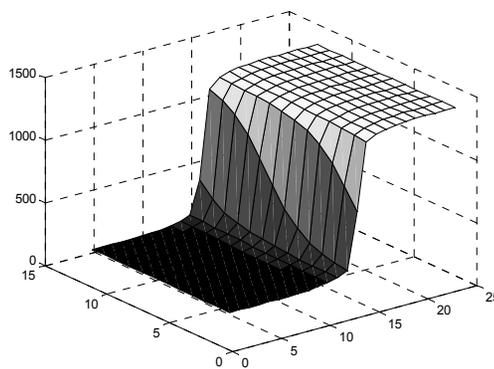
Stennis Space Center



MTFC  
not applied

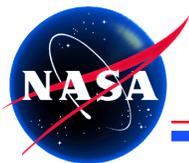


Measured



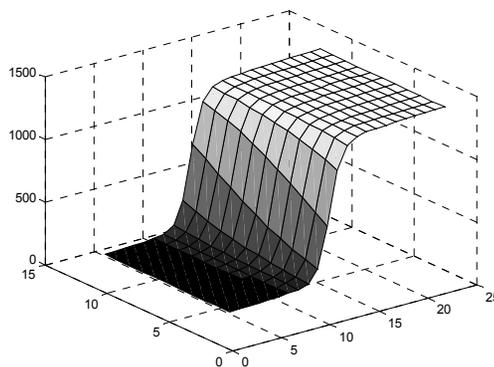
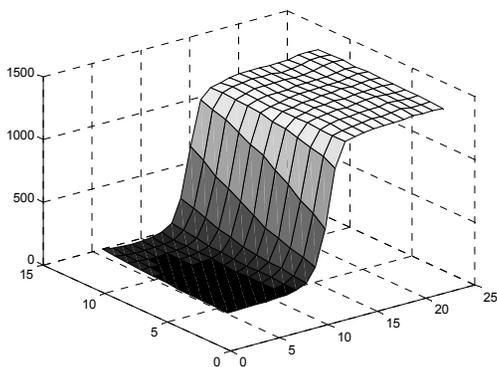
Best fit

MTFC  
applied

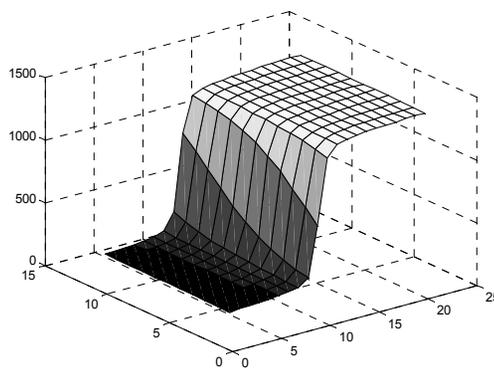
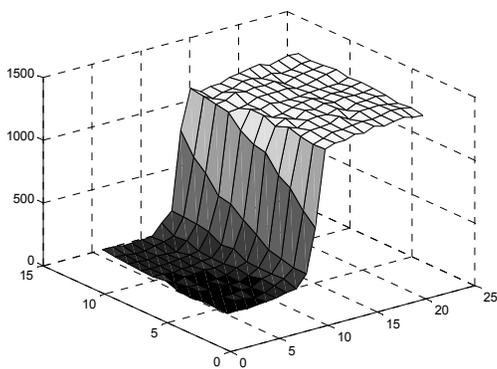


# Edge Responses: Northing, 80°

Stennis Space Center



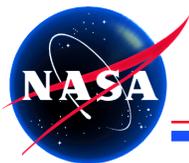
MTFC  
not applied



MTFC  
applied

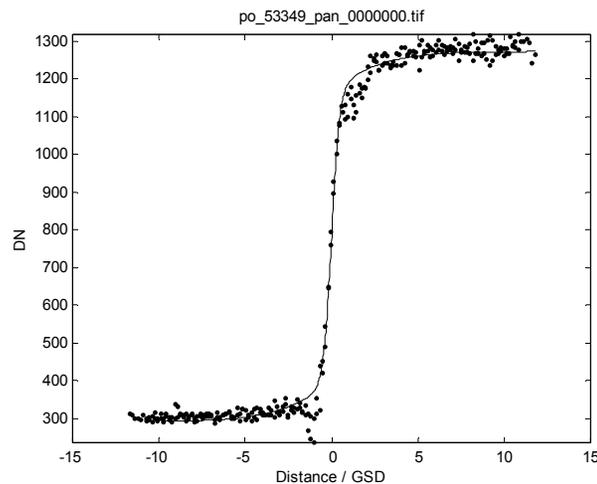
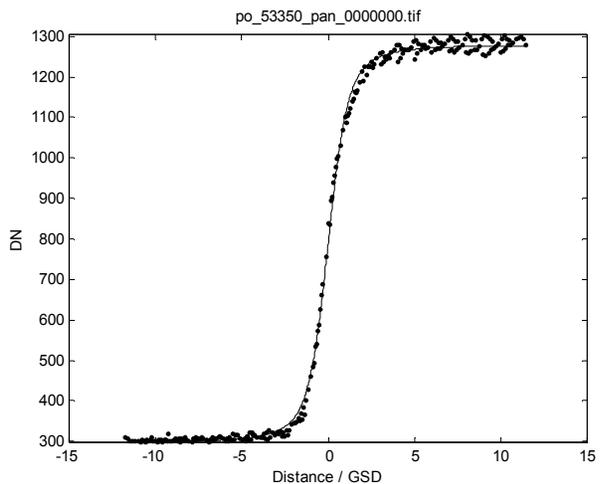
Measured

Best fit



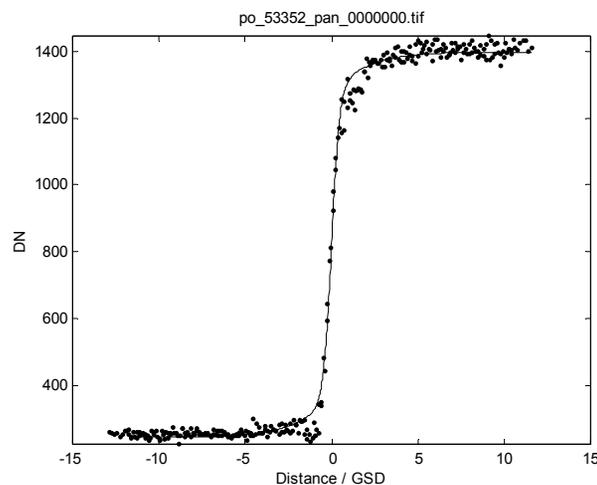
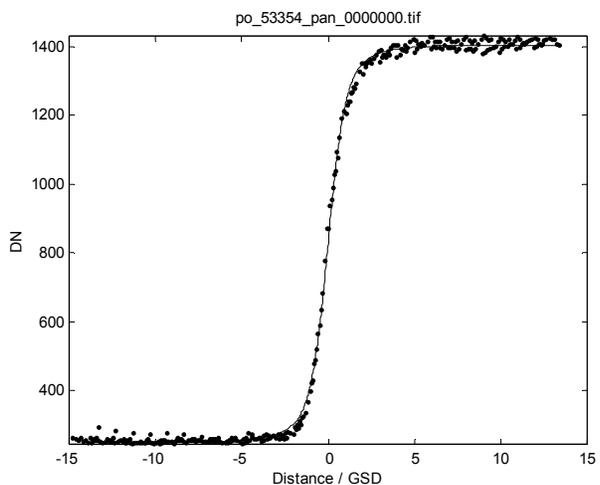
# Edge Response: Easting

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Superimposed edge responses and the fitted sigmoidal functions

60°

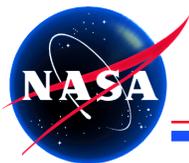


80°

Estimation of the edge tilt from the pixel (UTM) grid: about 9°

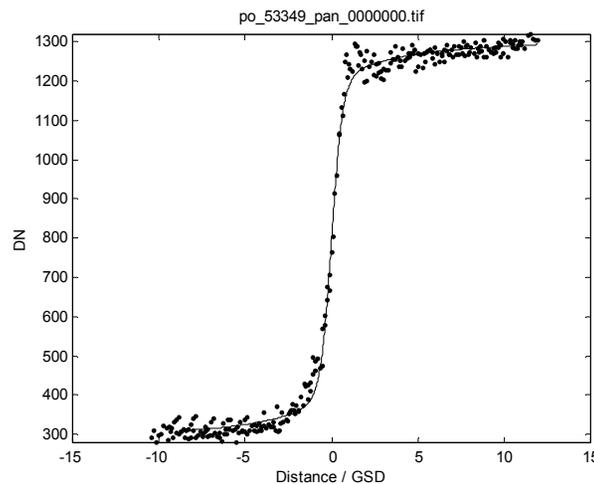
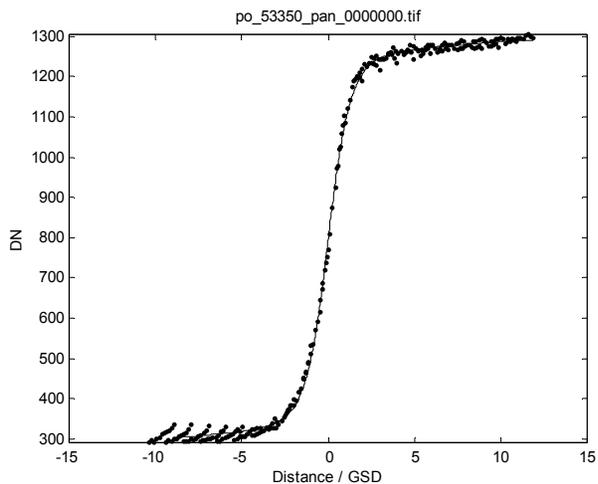
MTFC not applied

MTFC applied



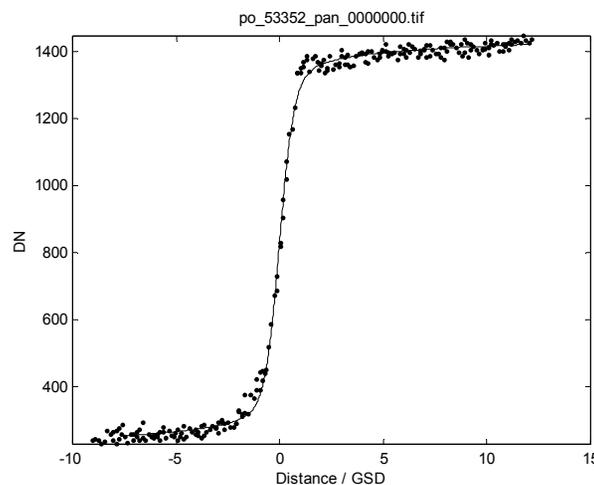
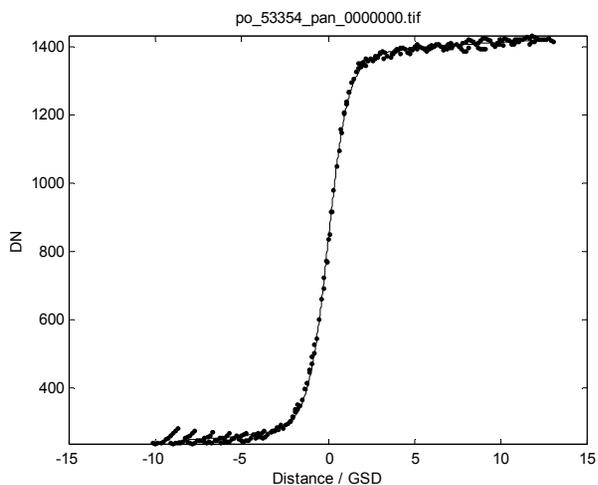
# Edge Response: Northing

Stennis Space Center



Superimposed edge responses and the fitted sigmoidal functions

60°

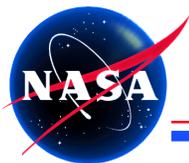


80°

Estimation of the edge tilt from the pixel (UTM) grid: about 8°

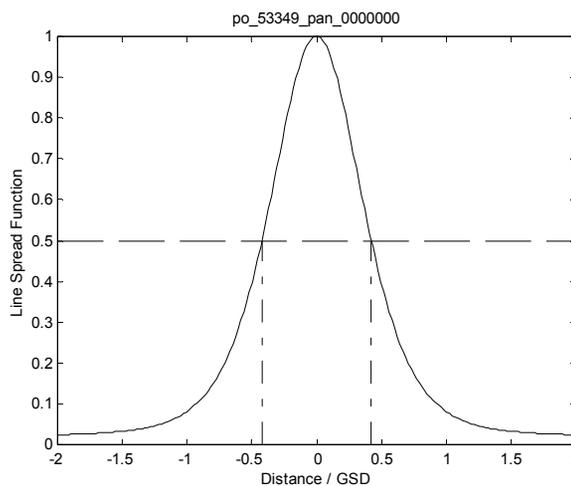
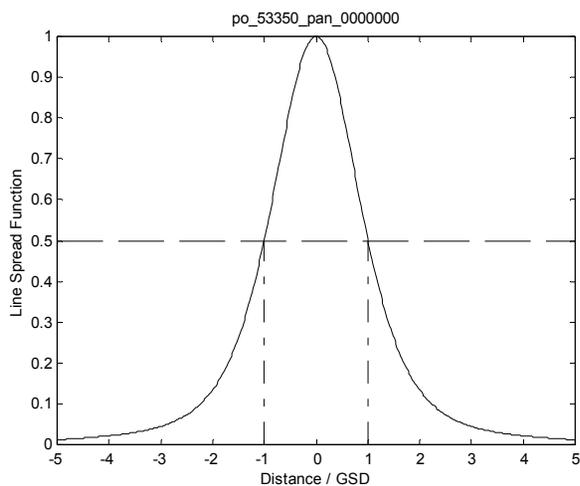
MTFC not applied

MTFC applied



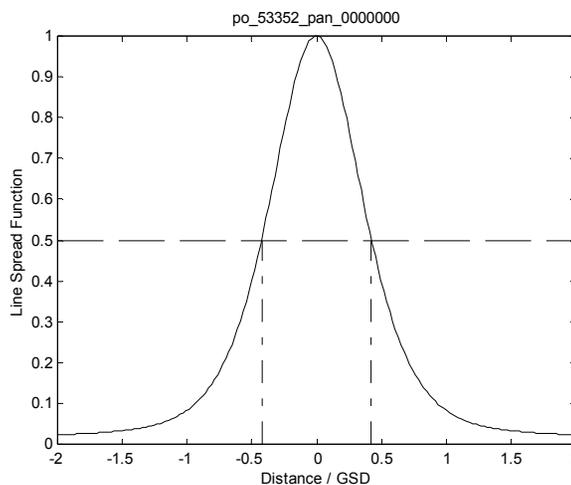
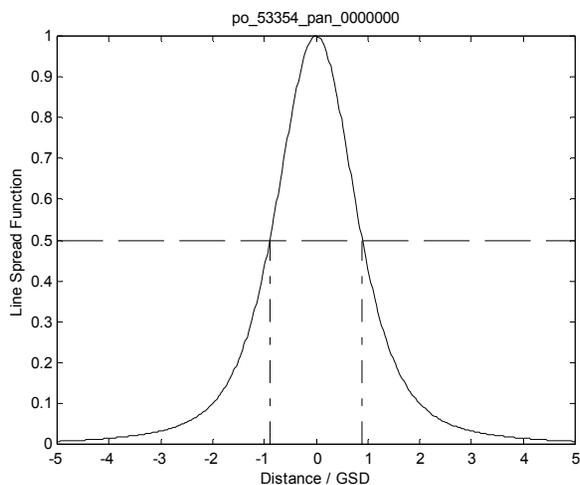
# Line Spread Function: Easting

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Line spread functions derived from the edge responses

60°

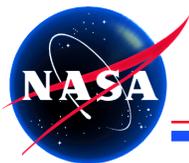


80°

Note the difference in distance scale between left and right column

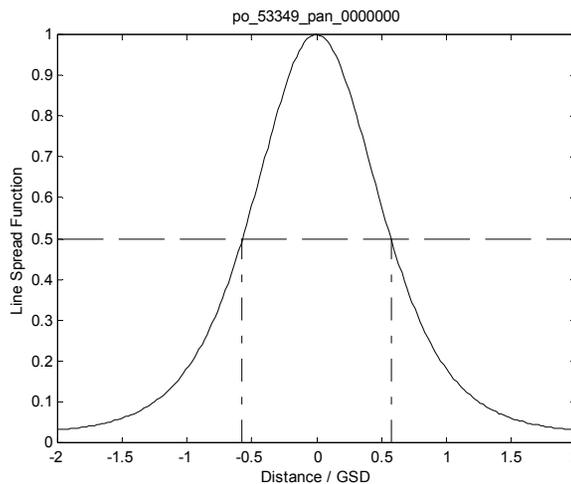
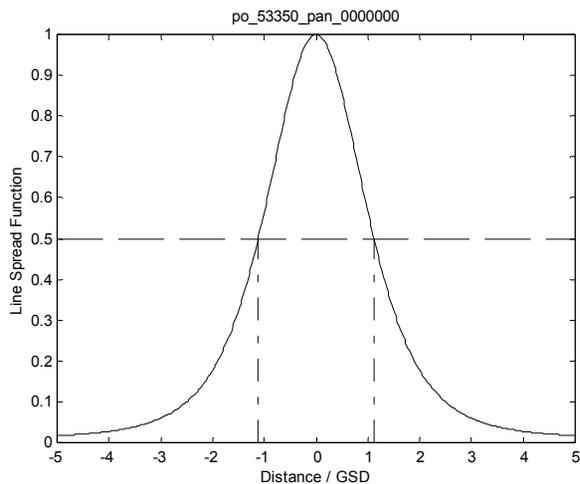
MTFC not applied

MTFC applied



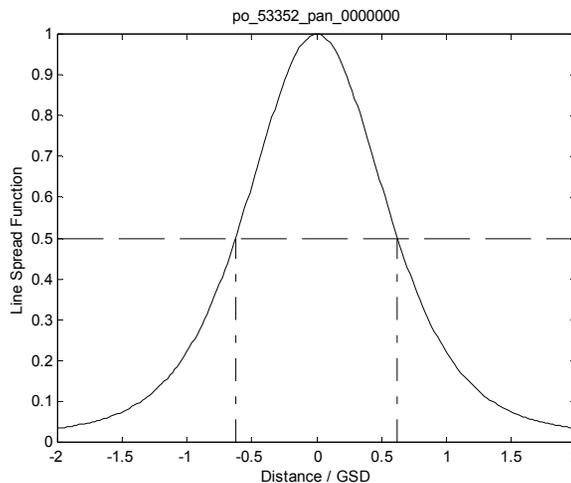
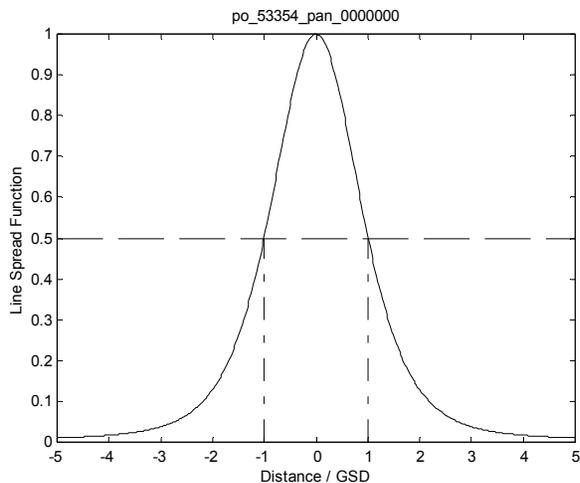
# Line Spread Function: Northing

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Line spread functions derived from the edge responses

60°



80°

Note the difference in distance scale between left and right column

MTFC not applied

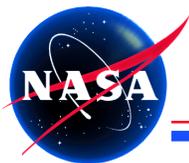
MTFC applied



# Summary: FWHM / GSD

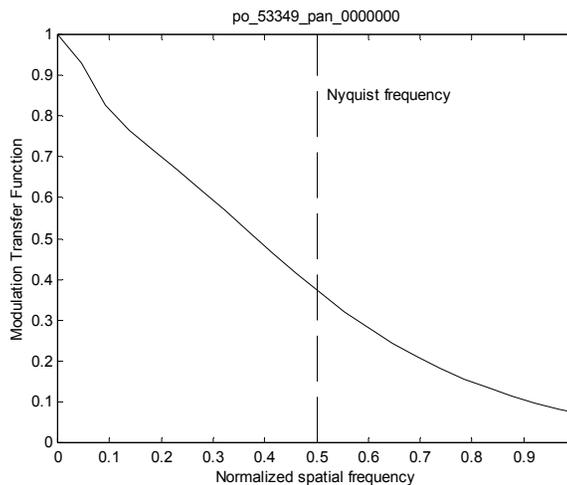
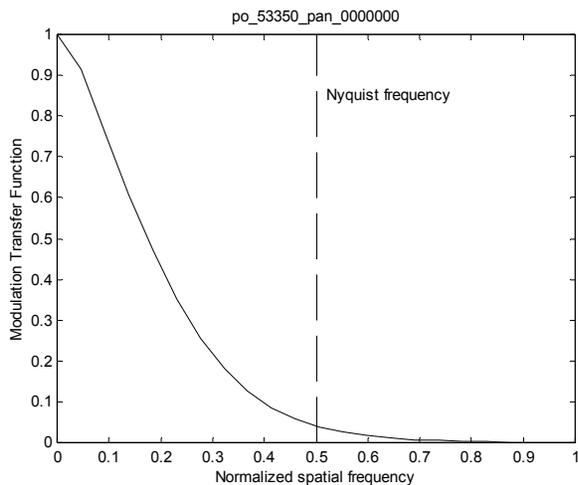
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	MTFC	Collection Elevation Angle	
		60°	80°
Easting	off	2.01	1.79
	on	0.85	0.85
Northing	off	2.23	2.01
	on	1.15	1.25



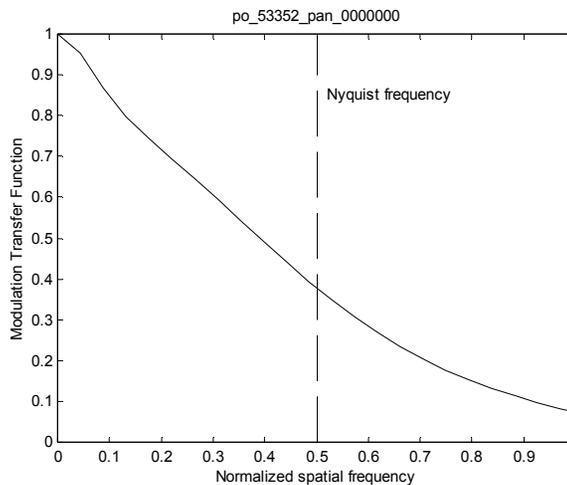
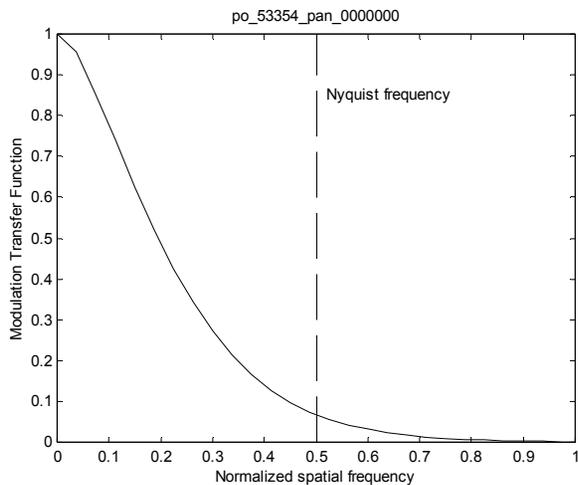
# MTF: Easting

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MTF estimated from the Line Spread Functions

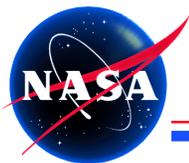
60°



80°

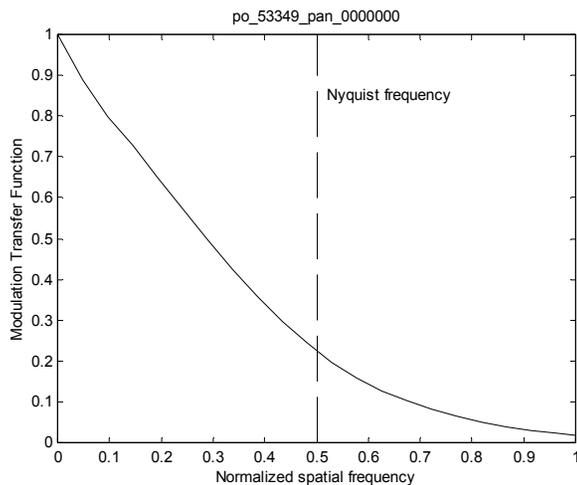
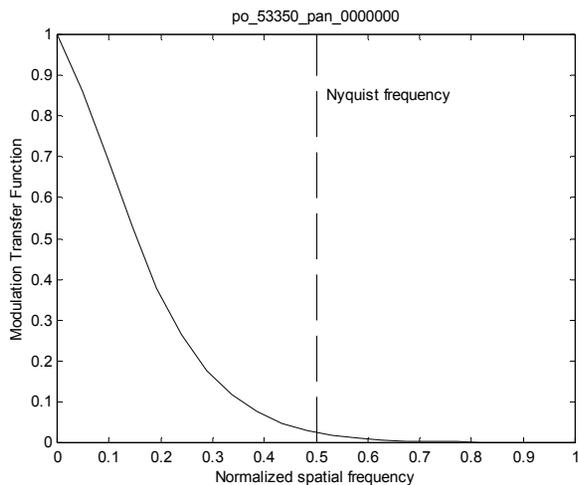
MTFC not applied

MTFC applied



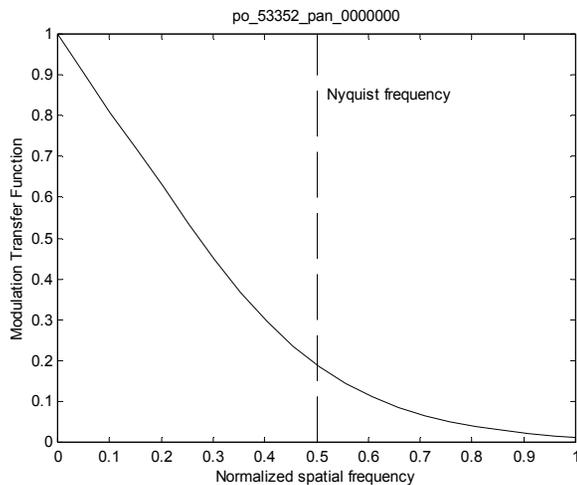
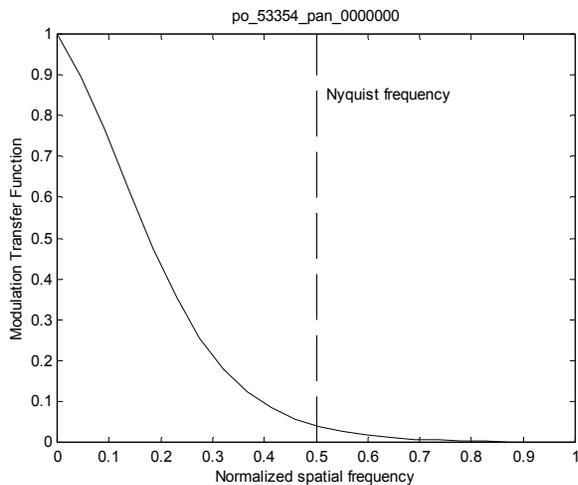
# MTF: Northing

Stennis Space Center



MTF estimated from the Line Spread Functions

60°



80°

MTFC not applied

MTFC applied